

CLAIMS

What is claimed is:

- 1 1. A fuel cell system including a cell stack
2 comprising a plurality of adjacent fuel cells, each
3 cell comprising a) anode plate means, b) cathode
4 plate means, and c) an electrolyte layer sandwiched
5 between said anode and cathode plate means;
6 said stack also including a hydrophobic barrier
7 layer having a first side and second side and being
8 sandwiched between and in contact with said anode
9 plate means of one of said fuel cells and said
10 cathode plate means of another of said fuel cells,
11 said barrier layer being porous to water vapor while
12 having a water intrusion pressure sufficiently high
13 to prevent liquid water from passing therethrough
14 under expected fuel cell system operating
15 conditions;
16 wherein one of either said anode or cathode plate
17 means defines, with said first side of said barrier
18 layer, channels for carrying liquid water adjacent
19 said first side of said barrier layer and out of
20 said fuel cell;
21 and, wherein the other one of said anode or
22 cathode plate means defines, with said second side
23 of said barrier layer, channels for receiving steam
24 from said liquid water channels and for carrying
25 that steam out of said fuel cells;
26 said fuel cell system also including a) means
27 connected to said liquid water channels for feeding
28 a stream of liquid water into said liquid water
29 channels during fuel cell operation; b) means for
30 sensing the temperature at which the fuel cells are
31 operating; c) temperature control means including
32 means i) for reducing the pressure within said steam
33 channels to below the vapor pressure of water within
34 said water channels to boil the water to produce

35 steam and evaporatively cool the cells, and ii) for
36 adjusting said steam channel pressure in response to
37 said temperature sensing means to control the amount
38 of evaporative cooling and maintain a desired fuel
39 cell operating temperature range.

1 2. The fuel cell system according to claim 1, wherein
2 said water channels are defined between said anode
3 plate means and said barrier layer and said steam
4 channels are defined between said cathode plate
5 means and said barrier layer.

1 3. The fuel cell according to claim 1, wherein said
2 electrolyte layer is a PEM.

1 4. The fuel cell system according to claim 3, wherein
2 said means (i) for reducing pressure includes a
3 vacuum pump in communication with said steam
4 channels and said means (ii) for adjusting said
5 steam channel pressure is a radiator for removing
6 heat from the steam after it leaves said steam
7 channels.

1 5. The fuel cell system according to claim 3, wherein
2 said anode plate is a porous, hydrophilic water
3 transport plate and said cathode plate is a porous,
4 hydrophilic water transport plate.

1 6. The fuel cell system according to claim 4, wherein
2 said anode plate is a porous, hydrophilic water
3 transport plate and said cathode plate is a porous,
4 hydrophilic water transport plate.

1 7. The fuel cell system according to claim 3, wherein
2 at least one of said anode plate and cathode plate
3 is a non-porous separator plate.

1 8. The fuel cell system according to claim 3, wherein
2 both said anode plate and said cathode plate are
3 non-porous separator plates.

1 9. The fuel cell system according to claim 4, wherein
2 at least one of said anode plate and cathode plate
3 is a non-porous separator plate.

1 10. The fuel cell system according to claim 4, wherein
2 both said anode plate and said cathode plate are
3 non-porous separator plates.

1 11. The fuel cell system according to claim 6,
2 including a water accumulator for receiving
3 condensed water from said radiator, wherein said
4 water feeding means includes water pump means for
5 pumping water from said accumulator into and through
6 said water channels.

1 12. In a stack of fuel cells, wherein adjacent cells
2 are separated by a porous, hydrophobic barrier layer
3 having a water intrusion pressure that prevents
4 liquid water from crossing between cells through the
5 barrier layer under normal operating conditions, the
6 cell on one side of the barrier layer defining a
7 flow channel for liquid water adjacent that one side
8 of the barrier layer, the cell on the other side of
9 the barrier layer defining a flow channel for steam
10 adjacent that other side of the barrier layer, said
11 water and steam flow channels being in vapor
12 communication with each other through the barrier
13 layer, the process of cooling the fuel cells by
14 evaporative cooling during fuel cell operation
15 comprising the steps of:
16 flowing liquid water into and through the water
17 flow channel and out of the fuel cell, the water
18 being heated within the water channel by heat
19 produced by the fuel cell; and,
20 causing the liquid water to boil as it flows
21 through the water channel by reducing the
22 pressure in the steam channel below the vapor
23 pressure of the flowing liquid water to convert
24 at least some of the water to steam that passes
25 through the barrier layer into the steam channel,
26 wherein the pressure in the steam channel is
27 increased or decreased during cell operation in

28 response to the operating temperature of the cell
29 to increase or decrease the operating temperature
30 of the cell to achieve a desired cell operating
31 temperature.

1 13. The cooling process according to claim 12, wherein
2 the step of reducing the pressure in the steam
3 channel includes drawing a vacuum in the steam
4 channel, and the step of increasing or decreasing
5 the pressure in the steam channel includes passing
6 the steam through a radiator after it leaves the
7 cell and controlling the amount of heat removed from
8 the steam within the radiator.

1 14. The cooling process according to claim 13, wherein
2 steam is condensed to water within the radiator and
3 at least a portion of the condensate is made
4 available for recirculation through said water
5 channels

1 15. The cooling process according to claim 13, wherein
2 each fuel cell includes a PEM and operates on
3 reactant gasses that are at substantially
4 atmospheric pressure, and the pressure in the steam
5 channels is controlled to maintain the cell
6 operating temperature between 150°F and 180°F.

1 16. A method for evaporatively cooling a plurality of
2 adjacent fuel cells, wherein each cell comprises an
3 electrolyte layer sandwiched between a porous anode
4 water transport plate and a porous cathode water
5 transport plate, the anode plate of one cell
6 extending from the electrolyte layer of the cell to
7 one side of a porous hydrophobic, electrically
8 conductive barrier layer separating the two adjacent
9 cells, and the cathode plate of the adjacent cell
10 extending from the electrolyte layer of said
11 adjacent cell to the other side of said barrier
12 layer, the steps of:

13 a)flowing liquid water adjacent one side of
14 the barrier layer through first channels
15 formed between one of the cell water transport
16 plates and the barrier layer;
17 b)drawing a vacuum in second channels formed
18 between the transport plate of the adjacent
19 cell and the other side of the barrier layer
20 to reduce the pressure in the second channels
21 to below the vapor pressure of the water in
22 the first channels to cause the liquid water
23 to boil and produce steam that passes through
24 the barrier layer into the second channels;
25 c)removing the steam from the second
26 channels; and,
27 d)controlling the amount of evaporative
28 cooling by controlling the steam pressure in
29 the second channels.

1 17. The method according to claim 16, wherein the
2 electrolyte layer is a PEM.

1 18. The method according to claim 16, wherein the step
2 (d) of controlling the amount of evaporative cooling
3 includes passing the steam from the second channels
4 through a radiator that includes a fan, and
5 controlling the speed of the fan to control the
6 steam pressure in the second channels.

1 19. The method according to claim 16, wherein in step
2 (d) the operating temperature of the cell is
3 continuously determined and the amount of
4 evaporative cooling is regulated by adjusting the
5 steam pressure within the steam channels in response
6 to the operating temperature to maintain or change
7 the operating temperature as desired.

1 20. The method according to claim 19, wherein the
2 electrolyte layer is a PEM.

1 21. The method according to claim 18, wherein the step
2 of passing the steam through a radiator includes

3 condensing steam to liquid water, wherein some of
4 that condensed liquid water is directed into a water
5 accumulator and recirculated through the first
6 channels as needed.